MULTIPURPOSE PULSE OXIMETER: OXYGEN SATURATION, BODY TEMPERATURE AND HEART RATE COUNTING METER

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INTRODUCTION

Medical devices can be categorized into two categories viz invasive and non-invasive methods. The invasive method needs a medical device to be inserted into the patient's body to investigate or carry out treatment on the patient. However, the non-invasive method is a way to check the health condition from the outside of the body. There is a huge market for non-invasive methods of measurement of the vital signs. The objective of this project is to design and implement a reliable, cheap, low powered, non-intrusive, and accurate system that can be worn on a regular basis and monitor the vital signs and displays the output on a doctor's cell phone. This data is easily accessible to the physician later (Mohammad, 2012).

The proposed design specifically deals with the signal conditioning and data acquisition of three vital signs: heart rate, oxygen saturation, and body temperature. The meter which gives these values together can be called a 'multipurpose pulse oximeter (MPPO)'. The most important clinical parameters in the evaluation of a critically ill patient are the pulse rate, oxygen saturation, temperature, blood pressure and respiratory rate. Monitoring and maintenance of these vital parameters during the first hour of trauma ('golden hour') or critical illness largely predicts the patient's overall outcome (William, 2006).

The currently available equipment for these monitoring devices are expensive, limiting their availability in most of the health care centers in Sri Lanka. The new design provides an easy way to assess the patient's vital parameters during the 'golden hour' and during the transfer period.

SYSTEM DESIGN AND METHODOLOGY

The multipurpose pulse oximeter consists of several hardware units as shown in Figure 1.

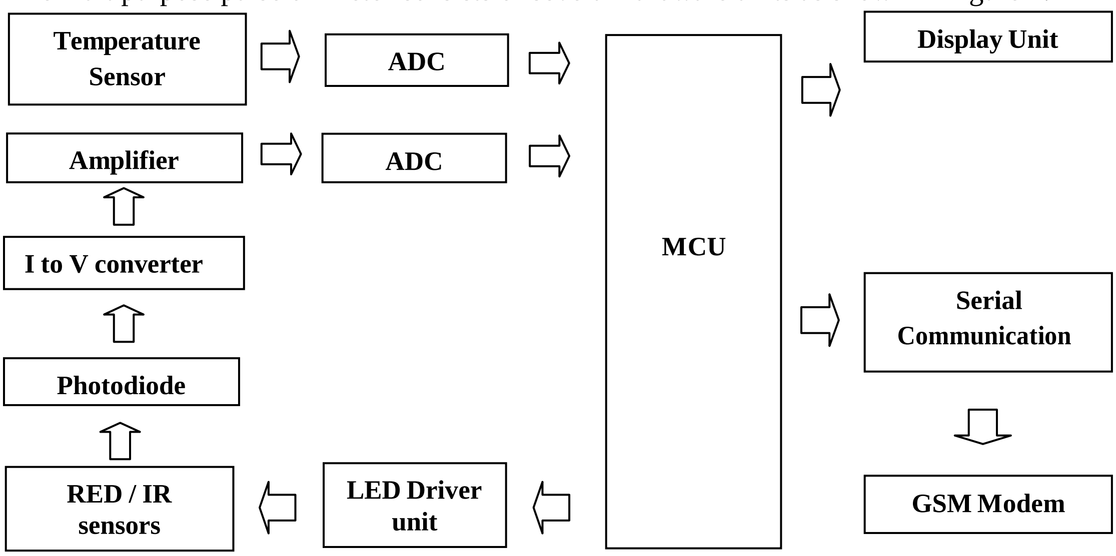

Figure 1: Block diagram of the MPPO system

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The MPPO can be divided into two units as measuring unit and sending unit. The temperature sensor (LM35) senses the body temperature and sends the analog value into the microcontroller (16F877A). The LED sensor unit consists of IR (LTR-4206) and RED (BL-S5131) sensors to emit IR and RED signals. The receiving side is equipped with a photodiode (BPW34). When the LEDs emit light, one by one photo detector produces current linearly proportional to the intensity of the light striking it. Then the current is converted to voltage, filtered DC values and noises and amplified. The analog value is fed to the microcontroller's ADC port.

Then the calculations are done at the microcontroller and the values are displayed on MPPO through liquid crystal display (JHD162A). Further the calculated values are sent through the interfacing circuit (MAX232) and GSM modem (SIM 300) to the on call doctor.

Body temperature measurement

The temperature sensor **(LM35)** is installed to measure the body temperature.

1. The output voltage from the sensor is converted to a 10-bit digital number ($2^{10}\approx1000$) using the internal ADC of the PIC16F877A.
2. The resolution of ADC is 1/1024-1 = 0.000977V/Count. Therefore, the digital output corresponding to any input voltage $V_{in} = V_{in} / 0.000977$.

   Eg: Surrounding temperature is 26.4 °C. Then output ADC, 0.264/0.000977 = 270
3. By reversing this process, for 270 from ADC the temperature = 270 * 0.000977 (V/Count) / 0.01 (V/°C) = 26.4 °C.

Oxygen saturation (SpO_2) measurement

Red light emitting diode **(LTL-4266N)** and infrared light emitting diode **(LTR-4206)** are used to transmit the light and the phototransistor **(BPW34)** works as a receiver. When the LED's emit light, one by one photo detector produces current linearly proportional to the intensity of light striking it. It produces current linearly proportional to the intensity of light striking it. The hemoglobin in blood will absorb the light and pass through the finger.

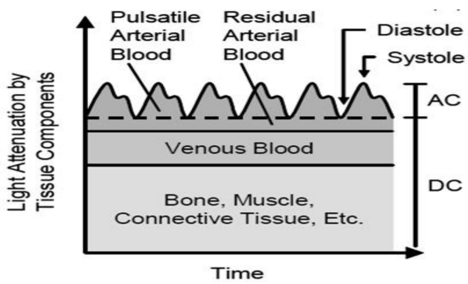

Figure 2: Expected output of the pulse oximeter (William, 2006)

Using Beer-Lambert`s law and this absorbance properties of blood, the following equation has been developed to calculate oxygen saturation (SpO_2).

$$SpO_2 = \frac{\varepsilon_{Hb\,r} - \varepsilon_{Hb\,ir}R}{(\varepsilon_{Hb\,r} - \varepsilon_{HbO_2\,r}) + (\varepsilon_{HbO_2\,ir} - \varepsilon_{Hb\,ir})R}$$

Where

$\varepsilon_{Hb\,r}$ Absorption coefficient of Red light in de-oxygenated hemoglobin

$\varepsilon_{Hb\,ir}$ Absorption coefficient of Infra-Red light in de-oxygenated hemoglobin

$\varepsilon_{HbO_2\,r}$ Absorption coefficient of Red light in oxygenated hemoglobin

$\varepsilon_{HbO_2\,ir}$ Absorption coefficient of Infra-Red light in oxygenated hemoglobin

R Ratio of the output intensity

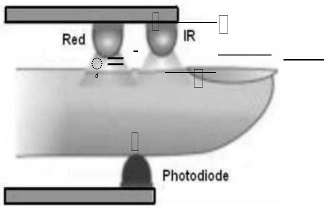

Figure 3: Schematic representation of SpO_2 sensor (Erica, 2010)

[illegible] is calculated in terms of voltage, not intensity. A ratio [illegible] comparing the two voltages at red and infrared wavelengths are given below.

$$[illegible] O_2 = \frac{[illegible]}{[illegible]}$$

V_{max} [illegible] Red light voltage exiting through the finger during systole

V_{min} [illegible] Red light voltage exiting through the finger during diastole.

Table 1: Absorption coefficient table

Light (wavelength)	**Absorption coefficient of Hb** $Lmm^{-1}cm^{-1}$	**Absorption coefficient of HbO_2** $Lmm^{-1}cm^{-1}$
Red - 640nm	0.81	0.08
IR - 960nm	0.18	0.29

Using the standard values given in the Table 1 and using the above equations the oxygen saturation ($[illegible] O_2$) is calculated.

Heart rate measurement

Heart rate is a byproduct of the signal acquired from the output of the photo-detector. Fig.02 shows the distance between two peaks of the output representing one cardiac cycle. If the time required in one cardiac cycle is "[illegible]" seconds (distance between the two peaks) then,

$$Heart\ rate = \frac{[illegible]}{[illegible]}$$

Viewing and sending the data via SMS

The measured three parameters are shown on the LCD display **(JHD162A)** and sents to the doctor via SMS through the GSM modem **(SIM 300).**

RESULTS AND DISCUSSION

To test the accuracy of the designed multipurpose pulse oximeter (MPPO)the results were compared with standard equipment.

Body temperature test

Table 2: Body temperature testing results

Patient	**Hospital's Thermometer value**	**MPPO reading**
Patient 1	39^0C	39^0C
Patient 2	41^0C	42^0C
Patient 3	37^0C	37^0C

Oxygen saturation (SpO_2) test

Table 3: SpO_2 testing results

Patient	Hospital's SpO_2 value	MPPO reading
Patient 1	100%	99%
Patient 2	100%	100%
Patient 3	99%	99%

Heart rate test

Table 4: Heart rate testing results

Patient	Doctor's HB value	MPPO reading
Patient 1	78bpm	78bpm
Patient 2	102bpm	98bpm
Patient 3	68bpm	68bpm

The authors could not test the equipment for oxygen saturation with the low SpO_2 values as then the patients were in critical when this happened. But for the other values MPPO provides a nearly accurate value. Further the authors could not test the equipment with a large no of patients as the patients were not medically fit.

CONCLUSIONS

This paper presents hardware and software designs of the multipurpose pulse oximeter (MPPO) which provides a low cost and secure meter which calculates and sends the heart rate, body temperature and oxygen saturation to the on call doctor. The use of a PIC microcontroller, GSM modem, sensors and LCD provide exciting possibilities. However as far as the industrial applications are concerned this can be viewed as a low cost, customized wireless remote monitoring system. Thus this solution can be customized to suit any other industrial applications. The use of GSM technology is provided to be controlled remotely and is cost-effective as compared to the existing systems. This MPPO can be modified for two other vital parameters viz, blood pressure and respiration rate in the future.

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